AUTOMATED VOLUME OF INTEREST EVALUATION FOR SEQUENCE DEVELOPMENT

Y. Wu[1,2], H. Du[3], F. Malone[1], S. Sidharthan[1], A. Ragin[4], and R. Edelman[1,2]
[1]Radiology, NorthShore University HealthSystem, Evanston, IL, United States, [2]Radiology, University of Chicago, [3]NorthShore University HealthSystem Research Institute, IL, United States, [4]Radiology, Northwestern University

INTRODUCTION: Improved contrast between gray and white matter enhances the conspicuity of neuroanatomical structures on MR images. Distinguishing these tissue types is also critical for brain volumetric measurements which have been used as markers of neurological progression. Studies aimed at optimizing the relative gray-white matter contrast, calculate an index (**Rgwc**), which is usually based on regions of interest (**ROI**). This approach requires manual placement of several small ROIs within gray and white matter regions. In this investigation, an alternative, volume of interest (**VOI**) approach was evaluated. This strategy, which is, based on automated segmentation, takes into account aggregate signal intensities of gray matter and white matter across the entire brain. This investigation systematically evaluated the utility of the ROI vs. the VOI image analysis methods for accurately reflecting image contrast quality when different RF width MR parameters were administered using a novel rapid isotropic brain sequence (Edelman 2009).

METHOD AND MATERIALS:

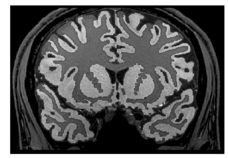
MR Image Acquisition: Under the guidelines of institutional review board, three volunteers (male 3; mean age 35.3Y, SD: 20.9 Y) were imaged using an 8-channel phased array coil (MRI Devices, Gainesville, FL) on a 3 Tesla General Electric (Waukesha, WI) HDx system. The 3D coronal SPGR acquisitions were repeated 5 times with a gradually increasing RF width from 1 00 to 2400 ums (five RFs: 100 ums, 400 ums, 800 ums, 1600 ums, and 2400 ums) using a spatially nonselective excitation (Edelman 2009). MR parameters include: 0.8 mm × 0.8 mm × 0.8 mm (0.51 mm^3) resolution. Half-Fourier acquisition was applied with a scan time of 4 minutes 42 seconds.

Image Analysis:

MR images were transferred offline to a Linux workstation.

1. ***Automated VOI Analysis*:** VOIs were generated with an automated segmentation FSL algorithm (Zhang 2001, Smith 2004). Scans with various RF were naturally aligned without posterior realignment. Gray and white matter VOIs were superimposed onto the 5 different RF scans to extract the mean signal intensity of gray matter and of white matter. VOIs were approximately 1,300,000 voxels for both gray matter and white matter. Additional morphological operation erosion was used to remove voxels at gray matter or white matter borders to minimize partial volume artifacts.
2. ***Manual ROI Analysis*:** ROIs were manually placed by an operator in order to obtain signal intensity Mean and SD in regions of bilateral cortical gray matter (cingulate gyri), insular gyri, caudate, putamen and neighboring white matter regions. ROIs were approximately 15-60 pixels (10-40 mm^2) for gray and white matter.

Figure 1 **Figure 2**



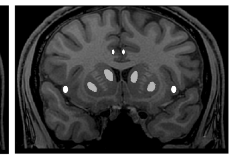


Figure 1: Automated VOI analysis: VOI of gray matter (white color) and white matter derived using segmentation. **Figure 2:** Manual ROI analysis. ROIs are illustrated (white dots).

The relative gray-white matter contrast (Rgwc) was calculated based on the mean signal intensity for gray matter (SIg) and white matter (SIw) using the following equation: Rgwc = (SIw – SIg) / SIg.

Statistical Analysis: Statistical methods included analysis of variance, independent t test, and Spearman intra-class correlation coefficients (**ICC**). All statistical tests were executed with SAS 9.1 using a significance level of 0.05, with Bonferroni correction for multiple comparisons.

RESULTS: The automated VOI analysis indicated high to excellent correlation between Rgwcs and RF variables (ICCs: 0.86083 ~ 0.99937). The VOI approach demonstrated a consistently increased pattern of tissue contrast associated with changes in RF (Figure 3). Results were less consistent for the manual ROI approach with overall ICCs ranging between -0.01953 to 0.6771 (Figure 4). Results based on the manual ROI approach were more ambiguous in interpretation compared to those based on VOI (Figures 3 - 4). For the VOI approach, Rgwc at 100 ums was significantly lower than that at 400ums, 800ums, 1600 ums, and 2400 ums (Bonferroni adjusted $p<0.001$), also the Rgwc at 400 ums was significantly lower than that at 1600 ums, and 2400 ums (Bonferroni adjusted $p=0.008$). For the manual ROI approach, significant differences were identified only for caudate and putamen (caudate: between 100 ums and 400, 800, 1600 and 2400 ums; putamen: between 100 to 400 ums and between 100 to 2400 ums) with no significant differences for Rgwc or correlations in cinglulate or insular cortex.

Figure 3

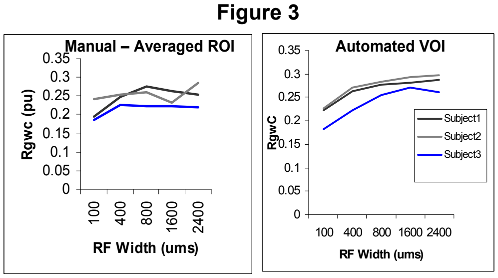


Figure 3: VOI analysis outperformed the ROI analysis and is more informative and consistent.

Figure 4

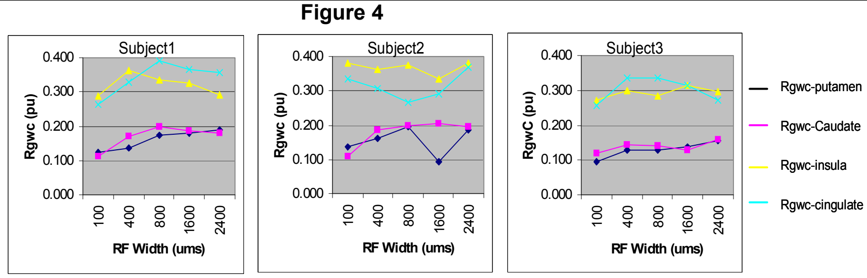


Figure 4: Commonly used ROI analysis shows ambiguous results among different brain regions and individuals.

CONCLUSION: In this investigation, when the same set of data was quantified, the automated VOI approach outperformed the standard manual ROI approach. Analysis based on automated VOI successfully detected subtle changes in tissue contrast and was consistently informative for MR sequence optimization. Results based on the standard ROI approach were ambiguous in different brain regions and individuals, and failed to document changes in image quality when scanning parameters were alternated in MR sequence optimization. Quantifying localized signal intensity using the standard ROI approach can subjective owing to the intrinsic signal variation in MR images from inhomogenities, regional B0 signal drift and distortion, which may account for the above observations. While, the ROI approach performed better for deep structures (caudate and putamen) than for regions at the brain surface, it failed to provide useful information for determining optimal RF width. The VOI method minimizes localized inhomogeneity variations, which is problematic when using the small ROI approach. These findings demonstrate the potential benefit of integrating advanced quantitative image analysis into sequence development routines to improve efficiency and accuracy.

REFERENCE: Edelman R et al. 2009 Invest. Radiol. Y Zhang et al. 2001 IEEE Smith SM et al. 2004 Neuroimage